Modelling Risk in Financial Services Systems: A Functional Risk Modelling Perspective

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Abstract. Financial market events in 2007 and 2008 pose a fundamental challenge for traditional Financial Services industry risk assessment approaches such as Value at Risk (VaR) models and capital adequacy risk measures. Unexampled events such as the liquidity crunch of the global credit markets, and its impact on individual Financial Services firms, clearly demonstrated the need to complement VaR risk models and traditional risk metrics with other types of risk models and metrics. The goal of the present paper is to introduce such a different type of risk modelling framework, i.e., functional risk modelling. Key concepts from resilience engineering are introduced and leveraged to define the approach. The primary goal of the proposed modelling framework is to identify functional dependencies between a firm's business functions and the functions that drive key behaviours of the global financial markets. An example from 2007's financial markets is used to illustrate the proposed framework, i.e., the rapid demise of the UK based residential mortgage firm Northern Rock.

1 INTRODUCTION

In the years 2007 and 2008, shockwaves propagated through the global Financial Services industry. These shockwaves were triggered by an unexampled event (Westrum, 2006), i.e., the global credit market crunch and its impact on other parts of the global Financial Services system. For example, the US firm Citigroup reported a 3rd quarter loss of 60% in 2007 due to the need to write-off more than 13 billion US dollars. Many other reputable global Financial Services organizations exhibited a similar pattern, i.e., UBS (Switzerland), Bank of America (USA), Merrill Lynch (USA) and Deutsche Bank (Germany). In addition, some Financial Services firms suffered catastrophic business failures, e.g., the US based global investment banking firm Bear Stearns Companies, Lehman Brothers and the UK based residential mortgage lending firm Northern Rock.

The 2007 global credit market crunch was an unexampled event, i.e., something so unexpected that it requires extreme imagination to think of, and that pushed organisations outside of their experience envelope. (Other categories of events are the regular threats that occur so often that it is cost effective for an organisation to develop a standard response, and irregular threats that are one-off events, for which it is not cost effective to prepare a standard response although it would not be impossible.) What happened in this case was the almost unimaginable scenario that an event originating from the US subprime markets propagated rapidly through the global Financial Services system with an unprecedented impact on practically every subsystem or component. One implication of the 2007-2008 market turmoil was the realisation that the use of historical data to predict the future obviously did not provide the required forward looking assessment of financial market behaviour (e.g., Bernstein, 2007). However, many traditional risk metrics and forecasting techniques used in the Financial Services industry do rely on historical data including value at risk (VaR) approaches used to determine market risk (Manganelli & Engle, 2001). In reaction to the events in 2007 and 2008, commentaries from policy makers (e.g., April 2008 report published by the Financial Stability Forum[1)] indicate that regulatory bodies and Financial Services experts are aware of the limitations of traditional risk metrics and of the need to augment the Basel II accord, the risk framework developed by the Bank for International Settlement (BIS, 2008).

In this paper, we suggest that the field of resilience engineering can provide the Financial Services industry with a different type of risk models, namely functional modelling approaches. The term 'functional' in the present work is used to denote the fact that models are focused on capturing behaviour of Financial Services functions performed to achieve specific goals and objectives rather than attempting to describe how they are implemented by any specific entity or component of the global financial system at a certain time point (cf., Merton & Bodie, 1995).

The primary objectives of this paper include:

- Provide a summary of the stress experienced by the global Financial Services System in 2007-2008.
- Introduce key concepts from the emerging field of resilience engineering and to leverage these to illustrate basic concepts of a functional modelling framework.
- Exemplify the modelling framework using the demise of the UK based residential mortgage firm Northern Rock.

Throughout the paper, the term 'risk' will be used to denote a state in which a financial system (or an entity of a financial system) is exposed to uncertainty of outcomes that could be either positive or negative.

[1)] The Financial Stability forum was formed in 1999 with the goal "…to promote international financial stability, improve the functioning of markets, and reduce systemic risk" (http://www.fsforum.org).

2 THE FINANCIAL SERVICES SYSTEM IN 2007-2008

The 2007-2008 financial markets turmoil has been the subject of many so called Financial Stability reports published by Central Banks.[2)] Other important entities such as the Financial Stability Forum's Working Group on Market and Institutional Risk, published a preliminary report in October 2007, followed by an intermediary report in February 2008 and a final report in April 2008 with recommendations for how to improve the resilience of the global financial system. While various reports differ with respect to language used to describe the behaviour of the financial markets in 2007-2008, all basically agree on the key elements of the turmoil.

Figure 1 reflects the view expressed by Bank of England (2007). The turmoil was triggered by an increased default rate in the US subprime mortgage market. In response to this increase in default rates, investors became more risk averse and as a result lost interest in financial instruments with an assumed exposure to the subprime markets, in particular investors, became weary of the structured finance markets, i.e., those markets focused on trading structured finance products. Such products are designed to enable funding on the basis of assets rather than the perceived risk of the entity seeking funds. A key process used to achieve this goal is securitization, i.e., the process of packaging assets into a new type of financial instrument (cf., Gallati, 2003, p. 246).

Fig. 1. Crisis "Phases" of the 2007 Financial Markets Turmoil (Based on Bank of England's 2007 Financial Stability Report's Chart 1)

Investor weariness spilled over to the short-term global credit markets and as a result major Financial Services firms faced increased liquidity risk. Due to the need to provide cover for funds typically available to investors on the short-term credit markets, global financial firms experienced a major deterioration of their balance sheets. The result was a perceived need to "hoard" cash and an increased aversion to risk. This triggered tensions on the inter banking lending market resulting in reduced

[2)] The first Financial Stability reports were published in 1996 - 1997 by the Bank of England, the Norwegian central bank Norges Bank and the Swedish central bank Riksbanken. Since then more than 50 central banks publish Financial Stability reports.

liquidity and higher inter banking interest rates (i.e., LIBOR). In parallel, complex asset classes experienced continued devaluation leading to an increased need for capital. As a result, some firms have continued to shed assets, e.g., Merrill Lynch, a USA based Financial Services Company, sold 30 billion dollars worth of asset in July-August 2008.

Central Banks such as Bank of England, the European Central Bank (ECB) and the US Federal Reserve Bank reacted to the turmoil by cutting interest rates and by pouring money into the global financial system, albeit using different methods. In the beginning, these activities were not coordinated, but over time, as the global impact was recognized, key activities such as improving liquidity became coordinated. In fact, the recommendations published by the Financial Stability Forum in April 2008 demonstrate a great degree of intent to coordinate activities including leveraging the Basel II accord (BIS, 2008), the previously mentioned capital framework developed by the Bank for International Settlement.

In the April 2008, the Financial Stability Forum provided a summary of how various risk management processes "broke down" (Financial Stability Forum, 2008, p. 16):

1. Regulators and supervisory bodies failed to identify the risks associated with Financial Services firms' structured financial products and other types of off-balance sheet entities. As a result firms ended up not having sufficient capital buffers to deal with asset devaluations and decreased investor risk appetite.
2. Financial firms misjudged the risk associated with off-balance sheet entities often due to an over-reliance on risk ratings provided by credit rating agencies (CRAs).[3)] In other words, instead of performing their own analysis, firms relied on ratings provided by specific companies such as Standard & Poor's.
3. Commonly used metrics to assess market risk, i.e., "…the risk of losses in on- and off-balance sheet positions arising from movements in market prices" (Gallati, 2003, p. 34), such as Value at Risk (VaR) could not be leveraged. Primary reasons for why VaR could not be used include that VaR requires historical data and the ability to "mark-to-Market". The latter, i.e., the need to assign an asset a value based on the current market price of the same or similar type of asset, could not be done in because there were no markets for the particular asset type! The reason for this was that investors' risk averseness had caused markets to quickly "dry up." As a result, valuations were model-based and of course likely not to reflect a realistic market value.
4. Investors (i.e., market participants) misjudged at least one of the following: a) Borrowers risk of defaulting, b) The dangers associated with making too many investments in a single type of assets, or, financial instrument, and c) The risks associated with reduced liquidity, i.e., the ability to turn an asset into cash without any impact on the value.

[3)] A credit rating agency is a company that assigns risk ratings to financial instruments. An example of a credit rating agency in the USA is Standard & Poor's.

3 KEY RESILIENCE ENGINEERING CONCEPTS

The first key premise in Resilience Engineering is that adverse outcomes are associated with an organization's lack of ability to anticipate significant changes in its risk exposure. Lacking this ability is most likely also associated with an organization's inability to pro-actively establish risk mitigants, i.e., processes that help to reduce impact of adverse events. As adverse events actually eventually occur, the organization's attempts to manage impact of these events are therefore likely to be opportunistic, or may even be scrambled (cf., Sundström & Hollnagel, 2006). Over time such an organization has a high probability to transition into a "catastrophic state", i.e., an irreversible state of failure.

The second key premise of a Resilience Engineering perspective is that focus moves away from system *stability* to system *sustainability*. As a result, performance variability is needed to evolve with an ever changing environment. Indeed, if stability is defined as a lack of variability, the system will not be resilient and is therefore almost guaranteed to fail! In the present work, we look at performance variability as changes in behaviour associated with a constant need to maintain a balance between "Healthy" and "Unhealthy" states, and a particular entity's ability to make these transitions is seen as an indicator of resilience (cf., Sundström & Hollnagel, 2006). When sustained performance is the key focus instead of stability, a primary capability of any system is to develop and maintain the ability to change over time. The need to change might be triggered by a need to adjust to internal and/ or external process changes.

An organization's risk exposure can increase due to internal and/or external process changes. The reason being that such process changes might result in outcomes associated with higher risk exposure for a part of, or, the whole system. To illustrate this point, we will consider how internal and an external process changes can bring about risk exposure changes for a Financial Services organization:

(1) **Internal Process Change:** Financial Services firm A decides to change its underwriting procedure to provide loans to borrowers that already have borrowed an amount that exceeds their annual income by 100%. This change will increase the firms risk exposure by making it more likely that its borrowers will default on their loans; thus eventually leading to higher losses. From a functional perspective, the underwriting process is part of the Financial Services function to "Transfer Economic Resources". Merton & Brodie (1995, p. 14) defined this function as function focused on transferring economic resources across industries and geographical regions.

(2) **External Process Change:** A credit rating agency changes the risk assessment methodology used to assign risk ratings to financial instruments. (The change in a rating agency's risk assessment process is also associated with the function to "Transfer Economic Resources".) This new risk assessment methodology systematically underestimates the risk associated with a specific type of financial instrument. Financial Services B does not have an ability to perform risk analysis and as a result simply accepts the credit agency's rating. The result is that the firm remains unaware of the increased risk exposure as it decides to invest in the instrument. Financial Services firm C has the ability to perform their own analysis

and decides to invest in the financial instrument with an awareness of the increased risk exposure. Unlike Financial Services firm B, firm C decides to dedicate resources to monitor the risk associated with the financial asset. As a result Financial Services firm C is in the position to be proactive relative to any market valuation changes, whereas firm B will be reactive. Figure 2 shows the situation for Financial Services firm B, while Figure 3 shows the situation for Financial Services firm C. Both figures use the Functional Resonance Analysis Method (FRAM; Hollnagel, 2004) to illustrate the two firms' exposure to unexpected variability. In a FRAM model, the risk for unexpected variability is represented by illustrating how functions may be coupled to each other. Such functional coupling provides a mechanism for understanding how unexpected variability may propagate through a system. Functional representations such as those in Figures 2 and 3 should be contrasted with the traditional flow-chart description of events as used in Figure 1.

A FRAM representation describes each of the essential functions of a system using six parameters (Figures 2 and 3 only show some of the functions hence do not represent a complete analysis). The six parameters are:

- Input (I): that which the function processes or transforms, or that which starts the function. In Financial Services, this could be the information that is modified, interpreted, or used in any other way by the function.

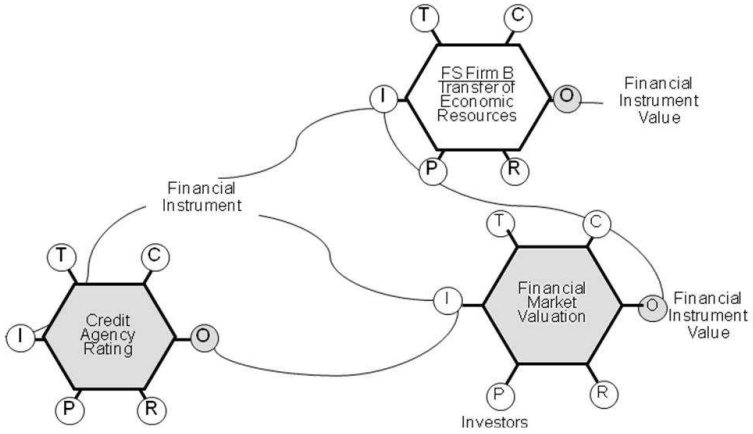

Fig. 2. Impact of external changes on Firm B's ability to sustain performance

- Output (O): that which is the result of the function, either an entity or a state change. In Financial Services, this can be economic resources for a party that previously did not have any economic resources. For example, Mr. Smith decides to go to a bank to apply for a mortgage and the bank does decide to transfer financial resources to Mr. Smith, i.e., provide Mr. Smith with a loan of some type.
- Preconditions (P): conditions that must be exist before a function can be executed. An example in Financial Services is the existence of a financial market with a defined demand and supply.

- Resources (R): that which the function needs, or consumes, to produce the output. This could be some type of financial assets and/or market participants such as investors.
- Time (T): temporal constraints affecting the function (with regard to starting time, finishing time, or duration). For example, the time of a transaction can greatly influence the value of an output in the Financial Services industry.
- Control (C): how the function is monitored or controlled. In Financial Services this can be a firm's risk management function and/or a regulatory function such as a Central Bank.

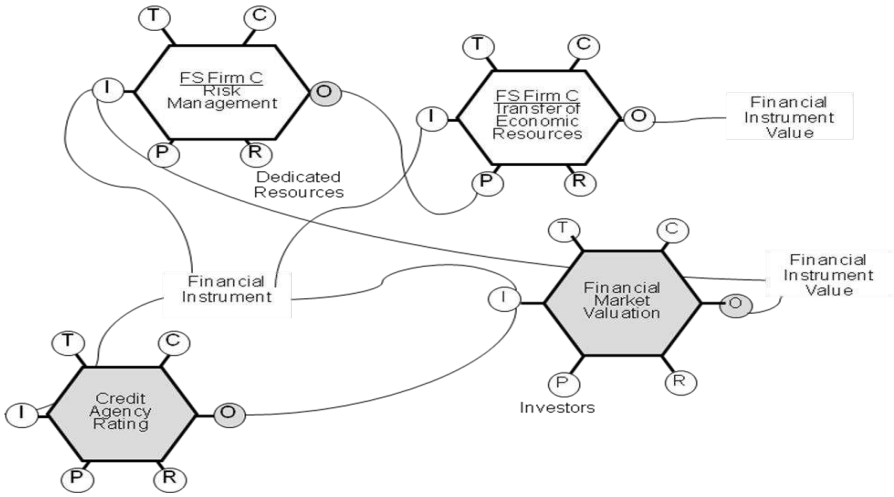

Fig. 3. Impact of external changes on Firm C's ability to sustain performance

Figures 2 and 3 illustrate one source of unexpected variability (indicated by shaded output) due to process changes, i.e., variability of a credit agency's rating due to a change in rating methodology. Any such change will have an impact on ratings (or perceptions of ratings) and will produce unexpected variability in any firms risk management function. As investors loose trust in credit ratings of certain financial instruments, any transfer of economic resources relying on these financial instruments will produce a negative outcome, i.e., no transfer of economic resources. One of the key drivers of investors' loss of trust could be ever increasing default rates due to poor underwriting procedures by yet other participants in the Financial Services system. A key variability of the 2007-2008 Financial Markets was indeed related to a loss of credibility of credit ratings, overtime investors grew more and more risk aversive as default rates of certain types of mortgages continued to rise. The result was unexpected behaviour of the "Transfer of Economic Resources" function which lead to the rapid demise of some companies. One of these was Northern Rock, a UK based mortgage lender.

4 EXAMPLE: NORTHERN ROCK

Northern Rock was listed on the London Stock Exchange in 1997 and was considered to be a very successful Financial Services firm. All of this changed as Northern Rock had to ask Bank of England for a line of credit on September 14,

2007 to overcome a "liquidity crunch". As a result Northern Rock experienced a classical bank run as customers were lining up to withdraw their savings. Northern Rock was nationalized in February 2008 and as a result is no longer traded as a public company. Figure 4 illustrates Northern Rock's business model.

Fig. 4. Northern Rock's Business Model

Basically, Northern Rock transferred economic resources to retail customers. Two sources of funding were used to transfer economic resources: Bank deposits, i.e., funds from banking customers' deposits. This source of funding was used to fulfil about 25% of customers' requests for mortgages. The other 75% were fulfilled by getting funds from the global credit markets. As we all know these markets started to experience major distress in the summer of 2007. The simplified representation in Figure 5 illustrates the risk that Northern Rock was taking due to its business strategy to leverage funding from global credit markets to fulfil 75% of the mortgages. Grey functions indicate that a function operates outside of Northern Rock's control.

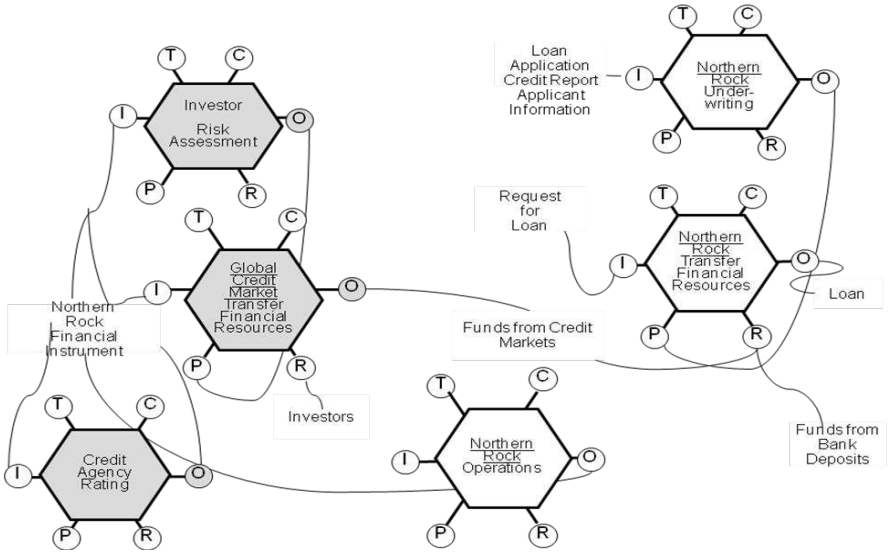

Fig.5. Functional view of Northern Rock's risk exposure

Note, that 75% of funding resources for Northern Rock's "Transfer of Economic Resources" function requires consistent (positive) output from the Global Credit Markets' "Transfer of Economic Resources" function. However, the key pre-condition for this function to operate successfully is Investors' risk assessment of Northern Rock's financial instruments. As financial markets became increasingly distressed in 2007, investors' trust in mortgage backed financial instruments severely deteriorated, and as a result Northern Rock experienced an acute liquidity crisis due to its high dependence on mortgaged backed securitization as a method of creating funds. A resilience engineering perspective combined with a simple analysis using a functional model to identify key dependencies could clearly have identified the risk to Northern Rock.

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